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(54) Ink jet printhead nozzle plates

(57) A method for making an inkjet printhead nozzle plate from a composite strip containing a nozzle layer (10) and an adhesive layer (24) is disclosed. The adhesive layer (24) is coated with a polymeric sacrificial layer (28) prior to laser ablating the flow features (16,18,20) in the composite strip. A method is also provided form improving adhesion between the adhesive layer (24) and the sacrificial layer (28). Once the composite strip containing the sacrificial layer (28) is prepared, the coated composite strip is then laser abated to form flow features (16,18,20) in the strip in order to form the nozzle plates. After forming the flow features, the sacrificial layer (28) is removed. Individual inkjet printhead nozzle plates are separated from the composite strip by singulating the nozzle plates with a laser.

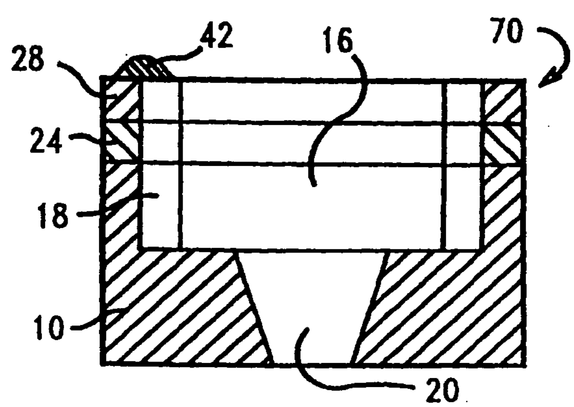

FIG. 6

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Description

The present invention relates to ink jet printhead nozzle plates, and to methods for making nozzle plates and for attaching a nozzle plate to a silicon heater substrate.

Printheads for ink jet printers are precisely manufactured so that the components cooperate with an integral ink reservoir to achieve a desired print quality. However, the printheads containing the ink reservoir are disposed of when the ink supply in the reservoir is exhausted. Accordingly, despite the required precision, the components of the assembly need to be relatively inexpensive, so that the total per page printing cost, into which the life of the assembly is factored, can be kept competitive in the marketplace with other forms of printing.

Typically the ink, and the materials used to fabricate the reservoir and the printhead, are not the greatest portion of the cost of manufacturing the assembly. Rather, it is the labor intensive steps of fabricating the printhead components themselves. Thus, efforts which lower the cost of producing the printhead have the greatest effect on the per page printing cost of the inkjet printer in which the printhead assembly is used.

One way to lower the cost of producing the printhead is to use manufacturing techniques which are highly automated. This saves the expense of paying highly skilled technicians to manually perform each of the manufacturing steps. Another important method for reducing costs is to improve the overall yield of the automated manufacturing process. Using a higher percentage of the printheads produced reduces the price per printhead by spreading out the cost of manufacture over a greater number of sellable pieces. Since process yields tend to increase as the number of process steps required to manufacture a part decrease, it is beneficial to reduce the number of process steps required to manufacture the printhead, or replace complex, low yield process steps with simpler, higher yield process steps.

Thermal inkjet printheads typically contain three and often less than about five major components, (1) a substrate containing resistance elements to energize a component in the ink, (2) an integrated flow features/ nozzle layer or nozzle plate to direct the motion of the energized ink and (3) a flow channel layer for flow of the ink to the resistance elements. The individual features which must cooperate during the printing step are contained in the two major components, which are joined together before use.

Nozzle plates for inkjet printheads are formed out of a film of polymeric material that is provided on a reel. The nozzle plates are semicontinuously processed as film is unrolled from the reel. An important part of the process is the removal of individual nozzle plates from the film so that the plates may be attached to a semiconductor chip surface for installation in the inkjet printhead. It is important that the removal process be conducted in a cost effective manner and that the quality of the resulting printhead structure be sufficient to achieve quality printed images.

In the past, an excimer laser was used to ablate the flow features and nozzle holes in a polymeric material to form nozzle plates and mechanical processes were used to cut the nozzle plates from the polymeric film. Mechanical punching is relatively inexpensive but is incapable of creating additional features on the nozzle plate that may be required for improving the adhesion between the nozzle plate and the semiconductor substrate to which it is attached. Mechanical punching also generates a significant quantity of debris which may interfere with the operation of the nozzle plate. It is also known that mechanical punches wear excessively at the corners and thus cannot achieve tight tolerances for any reasonable length of time, resulting in a high maintenance situation and a loss of product quality over time.

Typically, an adhesive is used to join the nozzle plates removed from the film to the printhead to provide a unitary structure. If the adhesive is applied to one of the nozzle plates or printheads before the manufacturing steps for that component are completed, then the adhesive layer may retain debris created during the various manufacturing steps. Often the debris is difficult to remove, and at the very least requires extra processing steps to remove, thus increasing the cost of the printhead. Additionally, if the debris is not completely removed the adhesive bond between the substrate and the nozzle layer will be impaired resulting in a printhead that either functions improperly or does not exhibit the expected utility lifetime.

If the adhesive is applied to one of the components after the features are formed in that component, additional labor intensive steps are required to ensure that the adhesive is positioned on the portions of the component that are to be used as bonding surfaces, and that the adhesive is removed from those portions of the component whose function will be inhibited by the presence of the adhesive. Not only do these extra steps add to the cost of the printhead, but any error in positioning the adhesive on the components will tend to reduce the yield of product from the printhead manufacturing process.

For example, if adhesive is left in a portion of the component such as a flow channel for the ink, then the proper function of that flow channel will be inhibited, and the printhead will be unusable. Alternately, if the adhesive does not adequately cover the bonding surfaces between the components, then the components may separate, allowing ink to leak from the completed assembly. Both of these conditions will lower the product yield, thereby increasing the cost of the printheads produced, as explained above.

It is an object of this invention, therefore, to provide a method for manufacturing an inkjet printhead that is highly automated.

It is another object of this invention to provide an inkjet manufacturing method that does not require addi-

tional process steps for the alignment and removal of adhesive.

It is a further object of this invention to provide a method for manufacturing an inkjet printhead in which the adhesive used to join the components does not attract and retain debris through subsequent process steps.

Another object of this invention is to provide a method for removing nozzle plates from a polymeric film.

A further object of the present invention is to provide a method of attaching a polymeric nozzle plate to a printhead.

The foregoing and other objects are provided by a method for making an inkjet printhead nozzle plate according to the present invention. In the present invention a composite strip containing a polymeric layer and optionally an adhesive layer is provided, and the adhesive layer is coated with a polymeric sacrificial layer. The coated composite strip is then laser ablated to form flow features comprising one or more nozzles, firing chambers and/or ink supply channels in the strip.

During the laser ablation step, slag and other debris created by laser ablating the composite strip adhere to the sacrificial layer, rather than to the adhesive layer. The sacrificial layer used to protect the adhesive layer during the laser ablation step is preferably a water soluble polymeric material, most preferably polyvinyl alcohol, which may be removed by directing jets of water at the sacrificial layer until substantially all of the sacrificial layer has been removed from the adhesive layer. Since the sacrificial layer is water soluble, it may readily be removed by a simple washing technique, and as a result of removal, will carry with it the debris adhered thereto. In this manner the nozzle structure is freed of the debris which may cause structural or operational problems without the use of elaborate cleaning processes. Furthermore, the adhesive may be applied directly to the nozzle structure before the nozzles are created by laser ablation, thus simplifying the manufacturing process.

A method is also provided for excising an inkjet printhead nozzle plate from the film of polymeric material by singulating, at least partially, all of the layers of the nozzle plate via use of a laser; subsequently removing the sacrificial layer. Once the nozzle plates are singulated and separated from the polymeric material, they are attached to a semiconductor substrate of an ink jet printhead.

Further objects and advantages of the invention will become apparent by reference to a detailed description of preferred embodiments, by way of example only, when considered in conjunction with the following illustrative drawings, in which like reference numerals denote like elements throughout the several views, and wherein:

Fig. 1 is top plan view, not to scale, of a nozzle plate having flow features formed in a composite strip of polymeric material.

Fig. 2 is a diagrammatical representation of the manufacturing method for forming flow features in a nozzle plate;

Fig. 3 is a cross-sectional view, not to scale, of a composite strip of polymeric material in which the nozzle plate is formed;

Fig. 4 is a cross-sectional view, not to scale, of a composite strip of polymeric material containing a sacrificial layer;

Fig. 5 is a side elevational view of a multi-zone heating oven used in the process of the invention;

Fig. 6 is a cross-sectional view, not to scale, of the nozzle and firing chamber configuration in the composite strip of polymeric material after laser ablation of the flow features;

Fig. 7 is top plan view showing partial singulation of a plurality of nozzle plates in a film of polymeric material;

Fig. 8 is a cross-sectional view, not to scale, of the nozzle configuration in the composite strip of polymeric material after laser singulation of a nozzle plate; and

Fig. 9 is a cross-sectional view, not to scale, of the nozzle and firing chamber in the completed composite strip of polymeric material after removal of the sacrificial layer.

Referring now to the drawings, there is depicted in Fig. 1 a plan view, viewed from the semiconductor substrate side of the section 70 of a nozzle plate 150 showing the major features of the nozzle plate 150. The nozzle plate 150 is made from a polymeric material 10 selected from the group consisting of polyimide polymers, polyester polymers, polymethyl methacrylate polymers, polycarbonate polymers and homopolymers, copolymers and terpolymers as well as blends of two or more of the foregoing, preferably polyimide polymers, which has a thickness sufficient to contain firing chambers, ink supply channels for feeding the firing chambers and nozzles holes associated with the firing chambers. It is preferred that the polymeric material has a thickness of about 10 to about 300 microns, preferably a thickness of about 15 to about 250 microns, most preferably a thickness of about 35 to about 75 microns and including all ranges subsumed therein.

The material from which the nozzle plate 150 is formed is provided as a continuous elongate strip or film of polymeric material, from which many nozzle plates may be formed, one after another, in a continuous or semicontinuous process. To aid in handling and providing for positive transport of the elongate strip of polymeric material 10 through the manufacturing steps, sprocket holes or apertures 12 may be provided in the strip or film.

The flow features formed in the polymeric material 10 and the optional adhesive layer 24 to form the nozzle plates by processes that will be more fully described below include an ink supply channel 14, which receives ink

from an ink reservoir (not shown) and supplies the ink to ink flow channels 16. The ink flow channels 16 receive the ink from the ink supply channel 14, and provide ink to the resistance elements (not shown) below the bubble chambers 18 which are also formed in the polymeric material 10 and the optional adhesive layer 24.

Upon energizing one or more resistance elements, a component of the ink is vaporized, creating a vapor bubble which imparts mechanical energy to a portion of the ink thereby ejecting the ink through a corresponding nozzle 20 of the nozzle plate 150. The ink exiting the nozzle 20 impacts a print medium, in a pre-defined pattern which becomes alpha-numeric characters and graphic images.

The composite strip 26 of polymeric material 10 may be provided on a reel 22 to the nozzle plate formation process such as that schematically illustrated in Fig. 2. Several manufacturers, such as Ube (of Japan) and E.I. DuPont de Nemours & Co., of Wilmington, Delaware commercially supply materials suitable for the manufacture of the nozzle plates under the trademarks of UPILEX or KAPTON, respectively. The preferred composite material 10 is a polyimide tape which contains an adhesive layer 24 as illustrated in Fig. 3.

The adhesive layer 24 is preferably any B-stageable adhesive material, including some thermoplastics. Examples of B-stageable thermal cure resins include phenolic resins, resorcinol resins, urea resins, epoxy resins, ethyleneurea resins, furane resins, polyurethanes, and silicon resins. Suitable thermoplastic or hot melt materials which may be used as adhesives include ethylene-vinyl acetate, ethylene ethyl acrylate, polypropylene, polystyrene, polyamides, polyesters, polyurethanes and preferably polyimides. The adhesive layer 24 is about 1 to about 100 microns in thickness, preferably about 1 to about 50 microns in thickness and most preferably about 5 to about 20 microns in thickness. In the most preferred embodiment, the adhesive layer 24 is a phenolic butyral adhesive such as that used in the laminate RFLEX R1100 or RFLEX R1000, commercially available from Rogers of Chandler, Arizona. At the position labeled "A" in Fig. 2, the composite strip 26 of polymeric material 10 and adhesive layer 24 has the cross-sectional configuration as shown in Fig. 3.

In order to protect the adhesive layer from debris during subsequent manufacturing steps, the adhesive layer 24 is temporarily protected with a sacrificial layer 28 as shown in Fig. 4. The sacrificial layer 28 is any polymeric material that may be applied in thin layers and is removable by a solvent that does not dissolve the adhesive layer 24 or the polymeric material 10. A preferred solvent is water, and polyvinyl alcohol is an example of a suitable water soluble sacrificial layer 28. Commercially available polyvinyl alcohol materials which may be used as the sacrificial layer include AIRVOL 165, available from Air Products Inc., of Allentown, Pennsylvania and EMS1146 from Emulsitone Inc. of Whippany, New Jersey as well as various polyvinyl alcohol resins from Aldrich. The sacrificial layer 28 is most preferably at least about 1 micron in thickness, and is preferably applied to the adhesive layer 24 by conventional techniques.

Methods for applying the sacrificial layer 28 to the adhesive layer 24 include dipping the composite strip 26 in a vessel containing the sacrificial layer material, spraying the sacrificial layer 28 onto the composite strip 26; printing such as by gravure or flexographic techniques the adhesive layer 24 with the sacrificial layer 28; coating by reverse gravure printing the adhesive layer 24 with the sacrificial layer 28; spinning the sacrificial layer 28 onto the adhesive layer 24; coating by reverse role coating or myer rod coating the adhesive layer 24 with the sacrificial layer 28; or knife coating or roll coating the adhesive layer 24 with the sacrificial layer 28.

A roll coating method for applying the sacrificial layer 28 to the composite strip 26 such as by coating roller 34 is shown in Fig. 2. At position B, the composite strip 26 now has a cross-sectional dimension as depicted in Fig. 4, with the adhesive layer 24 disposed between the polymeric material 10 and the sacrificial layer 28.

A method is also provided in the present invention for bonding the sacrificial layer 28 to the adhesive layer 24. The method includes the step of providing a composite strip 26 that contains the polymeric material 10 and the adhesive layer 24. At point A in the process(Fig. 2), composite strip 26 resembles that shown in Fig. 3. The sacrificial layer 28 is applied to the adhesive layer 24 by coating the adhesive layer 24 with the sacrificial layer 28.

Many of the conventional coating techniques may not provide a uniform, void-free coating of the sacrificial layer 28 on the adhesive layer 24. Since the presence of the sacrificial layer 28 is critical for removal of debris 42, the bond between the sacrificial layer 28 and the adhesive layer 24 must be sufficient to reduce significant delamination between the adhesive layer 24 and the sacrificial layer 28 during the early phases of laser ablation of the composite polymeric material 70. Delamination may occur when the sacrificial layer 28 has a low bonding strength. It has been found that the adhesion of the sacrificial layer 28 to the adhesive layer 24 can be improved significantly by post baking the composite strip 26 after coating the composite with the sacrificial layer 28 in a convection oven at a temperature ranging from about 60°C to about 100°C for a period of time ranging from about 30 minutes to about 60 minutes. In the alternative, the coated composite strip 26 may be baked by placing a heated roller in thermal proximity to the composite strip 26.

As shown in Fig. 5, the preferred embodiment for baking the coated composite strip 26 is by use of a multi-zone heating oven 100. During the baking procedure in of the multi-zone oven 100, the composite strip 26 from reel 21 is fed through the multi-zone oven 100 by a conveyor apparatus 110. The multi-zone heating oven 100 has the following zones, zone temperatures, and ap-

proximate temperature ranges:

Zone	Temperature	Temperature Range
1	30°C	25°C-35°C
2	60°C	45°C-65°C
3	77°C	75°C-85°C
4	95°C	90°C-100°C
5	105°C	100°C-110°C

In the preferred embodiment, the multi-zone heating oven 100 is 60 feet in length, and has a line speed of 15 feet per minute, which results in a total heating time of 4 minutes. Typically, the coating of the composite strip 26 and subsequent baking is performed before the composite strip 26 is rolled to form reel 22 containing the composite material. When the heated roller is applied to the coated composite strip 26 rather than the multi-zone heating oven 100, the composite strip 26 is preferably baked at a temperature from about 60°C to about 100°C.

The flow features of the section 70 of the nozzle plate 150, such as ink supply channel 14, flow channels 16, bubble chambers 18, and nozzles holes 20 as depicted in Fig. 1, are preferably formed by laser ablating the composite strip 26 in a predetermined pattern. A laser beam 36 for creating flow features in the polymeric material 10 may be generated by a laser 38, such as an F_2, ArF, KrCl, KrF, or XeCl excimer or frequency multiplied YAG laser. Laser ablation of the flow features to form the section 70 of nozzle plate 150 of Fig. 1 is accomplished at a power of from about 100 millijoules per centimeter squared to about 5,000 millijoules per centimeter squared, preferably from about 150 to about 1,500 millijoules per centimeter squared and most preferably from about 700 to about 900 millijoules per centimeter squared, including all ranges subsumed therein. During the laser ablation process, a laser beam with a wavelength of from about 150 nanometers to about 400 nanometers, and most preferably about 248 nanometers, applied in pulses lasting from about one nanosecond to about 200 nanoseconds, and most preferably about 20 nanoseconds, is used.

Specific features of the nozzle plates 150 are formed by applying a predetermined number of pulses of the laser beam 36 through a mask 40 used for accurately positioning the flow features in the composite material 26. Many energy pulses may be required in those portions of the composite material 26 from which a greater cross-sectional depth of material is removed, such as the nozzles holes 20, and fewer energy pulses may be required in those portions of the composite material 26 which require that only a portion of the material be removed from the cross-sectional depth of the composite material 26 such as the flow channels 16, as will be made more apparent hereafter.

The boundaries of the features of the nozzle plate 70 are defined by the mask 40 which allows the laser beam 36 to pass through holes, transparent, or semi-transparent regions of the mask 40 and inhibits the laser beam 36 from reaching the composite strip 26 in solid or opaque portions of the mask 40. The portions of the mask 40, which allow the laser beam 36 to contact the strip 26, are disposed in a pattern that corresponds to the shape of the features desired to be formed in the composite material 26.

During the laser ablation process of the composite strip 26 slag and other debris 42 are formed (Fig. 6). At least a portion of the debris 42 may redeposit on the strip 26. In the present invention, since the top layer of the strip 26 contains the sacrificial layer 28, the debris 42 lands on the sacrificial layer 28 rather than on the adhesive layer 24.

If the composite strip 26 did not have the sacrificial layer 28, then the debris 42 would land on and/or adhere to the adhesive layer 24. Debris which lands on and adheres to the adhesive layer 24 is difficult to remove often requiring complicated cleaning procedures and/or resulting in unusable product. The present invention not only makes removal of the debris 42 easier, but also increases yield of nozzle plates due to a reduction in non-usable product.

After the laser ablation of the composite strip 26 is completed, the section 70 of nozzle plate 150 at position C has the cross-sectional configuration shown in Fig. 6, as taken through one of the bubble chambers 18 and nozzle holes 20. As can be seen in Fig. 6, the polymeric material 10 still contains adhesive layer 24, which is protected by sacrificial layer 28. Debris 42 is depicted on the exposed surface of the sacrificial layer 28. The relative dimensions of the flow channel 16, bubble chamber 18, and nozzle 20 are also illustrated in Fig. 6.

In the present invention, a method is also provided for increasing the bonding strength between the nozzle plate 150 and a silicon substrate (not shown). As shown in FIGS. 7 and 8, the method includes the step of forming triangular shaped apertures 94 adjacent to at least two of the four singulation corners 90 of the nozzle plate 150 by use of laser 76 (Fig. 2) to laser ablate the apertures 94. The apertures 94 extend through all layers of the strip 26.

Once each individual nozzle plate 150 is excised from strip 26 by the cutting blades 56 (Fig. 2), adhesive/glue is placed at the aperture locations. In the preferred embodiment, the adhesive 96 is an Ultra Violet (UV) curable adhesive. After being excised from strip 26 and the apertures 94 filled with adhesive 96, the individual nozzle plates 150 are positioned on a silicon substrate wafer (not shown). The adhesive 96 is cured via exposure of the silicon substrate to a UV light source. Once the silicon substrate wafer is fully populated with nozzle plates 150, individual substrates are separated from the silicon wafer and attached to a printhead.

A method is also shown in Fig. 2 for singulating and removing the inkjet printhead nozzle plates 150 from the

laser ablated polymeric strip 26. In particular, the method includes the steps of providing a composite structure or strip 26 that contains a polymeric material 10, and as shown in FIG. 4, an adhesive layer 24, and a polymeric sacrificial layer 28. The method further includes the steps of partially laser singulating all layers of the nozzle plate 150 via laser 76 that is disposed subsequent to the excimer laser 38 in the process stream of Fig. 2. The method also includes the step of removing the nozzle plate 150 from the strip 26 via an excision cut using cutting blades 56.

The laser 76 used for partially singulating the nozzle plates may be selected from an infrared emitter type laser, a UV emitter-type laser like an excimer laser, a TEA CO_2 and a Q-switched YAG laser at primary wavelength or frequency multiplied. If the Q-switched YAG laser is used in the present invention, preferably the laser 76 will emit a wavelength of about 1.0 μm. Also preferably, the 0-switched YAG laser emits radiation onto the polymeric sacrificial layer 28 via laser beam 78 impulses lasting from about 8 nanoseconds to about 100 nanoseconds. The method for excising the inkjet printhead nozzle plate 70 from the reel of polymeric material 22 further includes a step of using an aperture plate 80 to shape the laser beam 78 of laser 76 so as to cut the polymeric sacrificial layer 28 at a width of about .005 inches.

In the preferred embodiment, the laser 76 is a TEA CO_2 laser. During the ablation process it is desired that heat dissipation around the singulated polymeric sacrificial layer 28 be limited to about 0 μm to about 37 μm from the cuts. It is understood that use of the aperture plate 80 to shape the laser beam of the TEA CO_2 laser to cut through all layers of the nozzle plate 150 at a width of about .005 inches, is also preferred, as with the use of the Q-switched YAG laser. The laser singulation of the polymeric sacrificial layer 26 is preferably performed at a speed of about 5 mm per second and greater by the TEA CO_2 laser.

Referring to Fig. 7, the composite strip 26, is moved along the plate shown in Fig. 2, by means of sprockets holes 88 that are disposed adjacent opposing edges 89 of the strip 26 on opposing sides of the nozzle plates 150. Singulation of the nozzle plates 150 is provided by laser 76 ablating through the sacrificial layer 28, adhesive layer 24, and polymeric material 10 to form slits 92 which are in a rectangular pattern around the perimeter of the nozzle plates 150.

The position of the slits 92 around the perimeter of the nozzle plates 150 are defined by projection mask 80, which allows the laser beam 78 to pass through apertures in the mask 80, and inhibits the laser beam 78 from reaching the composite strip 26 in other portions of the mask 80. The portions of the mask 80, which allow the laser beam 36 to contact the strip 26 are formed in set patterns.

Preferably, a galvo scanner, commercially available from General Scanning, Inc., of Chicago, Illinois, is to be used to form the slits 92 and to cut corners 90 in each nozzle plate 150. As shown in FIG. 7, each slit on the composite strip 26 preferably extends through the sacrificial layer 28, adhesive layer 24, and polymeric material 10. The slits 92 in the composite strip 26 greatly aid in removal of each individual nozzle plate 150 using cutting blades 56.

When the sacrificial layer 28 is a water soluble material, removal of the sacrificial layer 28 and debris 42 thereon upon completion of the laser ablation steps is preferably accomplished by directing water jets 44 toward the strip 26 from water sources 46 (Fig. 2). Alternatively, the sacrificial layer 28 may be removed by soaking the strip 26 in a water bath for a period of time sufficient to dissolve the sacrificial layer 28. The temperature of the water used to remove the sacrificial layer 28 may range from about 20°C to about 90°C. Higher water temperatures tend to decrease the time required to dissolve a polyvinyl alcohol sacrificial layer 28. The temperature and type of solvent used to dissolve the sacrificial layer 28 is preferably chosen to enhance the dissolution rate of the material chosen for use as the sacrificial layer 28.

The debris 42 and sacrificial layer 28 are contained in an aqueous waste stream 48 which is removed from the strip 26. Since the debris 42 was adhered to the sacrificial layer 28, removal of the sacrificial layer 28 also removed substantially all of the debris 42 formed during the laser ablation step. Because a water soluble sacrificial layer 28 is used, removal of the sacrificial layer 28 and debris 42 does not require elaborate or time consuming operations. Furthermore, the presence of the sacrificial layer 28 during the laser ablation process effectively prevents debris 42 from contacting and adhering to the adhesive layer 24. Because the method uses a sacrificial layer to protect the adhesive layer, the adhesive layer 24 may be attached to the polymeric material 10, rather than the substrate prior to laser ablation, thus simplifying the printhead manufacturing process.

After removal of the sacrificial layer 28, the adhesive coated composite strip 26 at position D has a cross-sectional configuration illustrated in Fig. 9. As can be seen in Fig. 9, the structure contains the polymeric material 10 and the adhesive layer 24. The sacrificial layer 28 which previously coated the adhesive layer 24 has been removed.

Sections 50 containing individual nozzle plates 150 are separated one from another by cutting blades 56, and are then subsequently attached to silicon heater substrates. The adhesive layer 24 is used to attach the polymeric material 10 to the silicon substrate.

Prior to attachment of the polymeric material 10 to the silicon substrate, it is preferred to coat the silicon substrate with an extremely thin layer of adhesion promoter. The amount of adhesion promoter should be sufficient to interact with the adhesive of the nozzle plate 150 throughout the entire surface of the substrate, yet the amount of adhesion promoter should be less than an amount which would interfere with the function of the

substrates electrical components and the like. The nozzle plate 150 is preferably adhered to the silicon substrate by placing the adhesive layer 24 on the polymeric material 10 against the silicon substrate, and pressing the nozzle plate 150 against the silicon substrate with a heated platen.

In the alternative, the adhesion promoter may be applied to the exposed surface of the adhesive layer 24 before application of the sacrificial layer 28, or after removal of the sacrificial layer 28. Well known techniques such as spinning, spraying, roll coating, or brushing may be used to apply the adhesion promoter to the silicon substrate or the adhesive layer. A particularly preferred adhesion promoter is a reactive silane composition, such as DOW CORNING Z6032 SILANE, available from Dow Corning of Midland, Michigan.

It is also preferred to coat the substrate with a thin layer of photocurable epoxy resin to enhance the adhesion between the nozzle plate and the substrate before attaching the nozzle plate to the substrate and to fill in all topographical features on the surface of the chip. The photocurable epoxy resin is spun onto the substrate, and photocured in a pattern which defines the ink flow channels 16, ink supply channel 14 and firing chambers 18. The uncured regions of the epoxy resin are then dissolved away using a suitable solvent.

A preferred photocurable epoxy formulation comprises from about 50 to about 75 % by weight gamma-butyrolactone, from about 10 to about 20% by weight polymethyl methacrylate-co-methacrylic acid, from about 10 to about 20% by weight difunctional epoxy resin such as EPON 1001F commercially available from Shell Chemical Company of Houston, Texas, from about 0.5 to about 3.0% by weight multifunctional epoxy resin such as DEN 431 commercially available from Dow Chemical Company of Midland Michigan, from about 2 to about 6% by weight photoinitiator such as CYRACURE UVI-6974 commercially available from Union Carbide Corporation of Danbury and from about 0.1 to about 1% by weight gamma glycidoxypropyltrimethoxysilane.

Claims

1. A method for making nozzle plates for an ink jet printer that comprises:

   (a) providing a strip comprising a polymeric material with or without an adhesive layer;
   (b) coating the strip with a polymeric sacrificial layer to form a composite strip;
   (c) ablating nozzle holes, flow features, or nozzle holes and flow features in the composite strip with a first laser; and
   (d) removing the sacrificial layer from the composite strip.

2. The method of Claim 1 further comprising singulating the coated composite strip with a second laser to provide individual nozzle plates and removing the singulated nozzle plates from the composite strip.

3. The method of Claim 2 wherein the second laser is an infrared emitter laser or a UV emitter laser.

4. The method of Claim 2 wherein the second laser is a Q-switched YAG laser.

5. The method of Claim 4 wherein the Q-switched YAG laser emits a laser beam with a wavelength of about 1.0 μm.

6. The method of Claim 4 or 5, wherein the Q-switched YAG laser emits radiation onto the composite strip in pulses lasting from about 8 nsec to about 100 nsec.

7. The method of Claim 2 wherein the second laser is a TEA CO_2 laser.

8. The method of Claim 7 wherein the TEA CO_2 laser limits slag buildup adjacent the singulated composite strips from about 0 μm to about 10 μm in height.

9. The method of Claim 7 or 8 wherein the TEA CO_2 laser limits heat dissipation around the singulated composite strips to a distance of from about 0 μm to about 37 μm.

10. The method of any of Claims 2 to 9 wherein an aperture plate is used to shape the laser beam emitted by the second laser in order to slit the composite strip at a width of about .005 inches (0.013mm).

11. The method of Claim 10 wherein the slits in the composite strip are made by using a galvo scanner.

12. The method of any of Claims 2 to 9 wherein a projection mask is used to shape the second laser beam in order to provide a slit pattern in the composite strip.

13. The method of any of Claims 2 to 9 wherein singulation of the composite strip with the second laser is performed at a speed of about 5 mm per second or greater.

14. A method for attaching a polymeric nozzle plate to a silicon heater substrate, which comprises the steps of:

    (a) providing a composite material containing a polymeric layer and an adhesive layer containing a first adhesive;
    (b) ablating the composite material to form noz-

zle plates having four corners;
(c) forming at least one aperture on the nozzle plate;
(d) separating individual nozzle plates from the composite material;
(e) contacting the adhesive layer of the nozzle plate with a silicon substrate;
(f) filling the aperture with a second adhesive; and
(g) curing the adhesives.

15. The method of Claim 14 wherein the aperture is formed in at least the adhesive layer of the nozzle plate.

16. The method of Claim 14 or 15 wherein the second adhesive is a UV curable adhesive.

17. The method of Claim 16 further comprising curing the UV curable adhesive by exposing the nozzle plates to a UV light source.

18. The method of any preceding claim, wherein step (a) comprises providing a composite strip containing a nozzle layer and an adhesive layer, and step (b) comprises applying a polymeric sacrificial layer to the adhesive layer, the method further comprising the step of heating the adhesive layer and sacrificial layer to a temperature sufficient to improve the adhesion between the sacrificial layer and the adhesive layer.

19. A method of adhering a polymeric sacrificial layer to a composite material used to provide inkjet printhead nozzle plates, which comprises the steps of:

(a) providing a composite strip containing a nozzle layer and an adhesive layer;
(b) applying a polymeric sacrificial layer to the adhesive layer; and
(c) heating the adhesive layer and sacrificial layer to a temperature sufficient to improve the adhesion between the sacrificial layer and the adhesive layer.

20. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by dipping the adhesive layer in the polymeric sacrificial layer.

21. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by spraying the polymeric sacrificial layer onto the adhesive layer.

22. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by printing the polymeric sacrificial layer onto the adhesive layer.

23. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by reverse printing the polymeric sacrificial layer onto the adhesive layer.

24. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by spinning coating the sacrificial layer onto the adhesive layer.

25. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by reverse roll coating or myer rod coating the polymeric sacrificial layer onto the adhesive layer.

26. The method of Claim 18 or 19 wherein the sacrificial layer is applied to the adhesive layer by knife over rolling the polymeric sacrificial layer onto the adhesive layer.

27. The method of any of Claims 18 to 26 wherein the composite strip containing the sacrificial layer and adhesive layer is heated by placing a heated roller in thermal proximity to the composite strip.

28. The method of Claim 27 wherein the heated roller bakes the polymeric sacrificial layer at a temperature ranging from about 60°C to about 100°C.

29. The method of Claim 27 or 28 wherein the composite strip is baked for about 30 to about 60 minutes.

30. The method of any of Claims 18 to 26 wherein the composite strip containing the adhesive layer and sacrificial layer is heated in a multi-zone heating oven.

31. The method of Claim 30 wherein the multi-zone heating oven has a first zone with a temperature ranging from about 25°C to about 35°C.

32. The method of Claim 30 or 31 wherein the multi-zone heating oven has a second zone with a temperature ranging from about 45°C to about 65°C.

33. The method of Claim 30, 31 or 32 wherein the multi-zone heating oven has a third zone with a temperature ranging from about 75°C to about 85°C.

34. The method of any of Claims 30 to 33 wherein the multi-zone heating oven has a fourth zone with a temperature ranging from about 90°C to about 100°C.

35. The method of any of Claims 30 to 34 wherein the multi-zone heating oven has a fifth zone with a temperature ranging from about 100°C about 110°C.

36. The method of any of Claims 18 to 26 wherein the

polymeric sacrificial layer is heated by placing the composite strip in a convection oven.

37. The method of Claim 36 wherein the composite strip is heated for about 30 to about 60 minutes.

38. A method of excising an ink jet printhead nozzle plate from a film of polymeric material, comprising the steps of:

(a) providing a strip of polymeric material;
(b) coating the strip with a polymeric sacrificial layer to form a composite strip;
(c) singulating, at least partially, all of the layers of the composite strip by means of a laser; and
(d) removing the sacrificial layer.

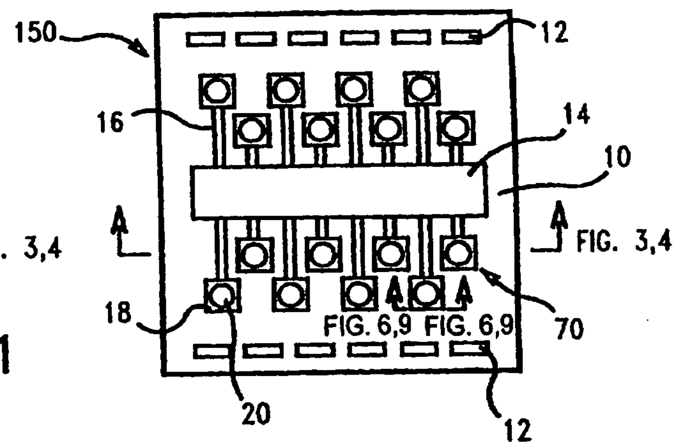

FIG. 1

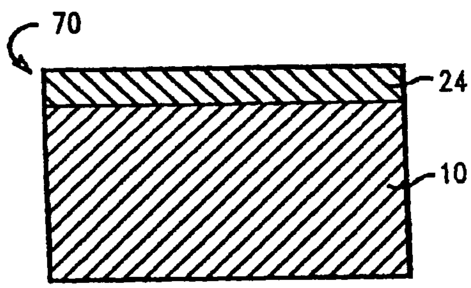

FIG. 3

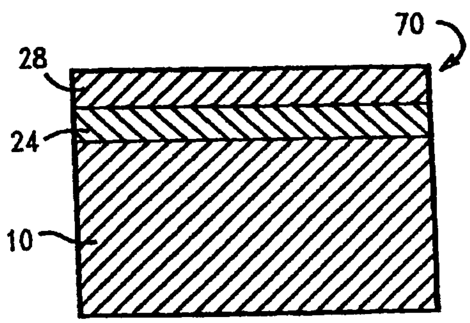

FIG. 4

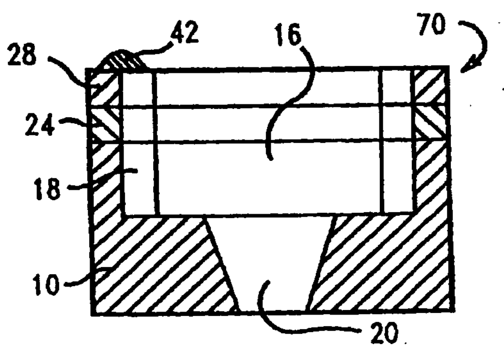

FIG. 6

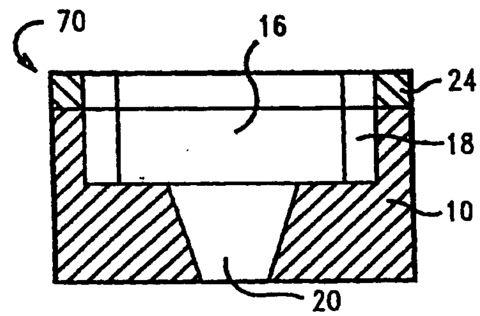

FIG. 9

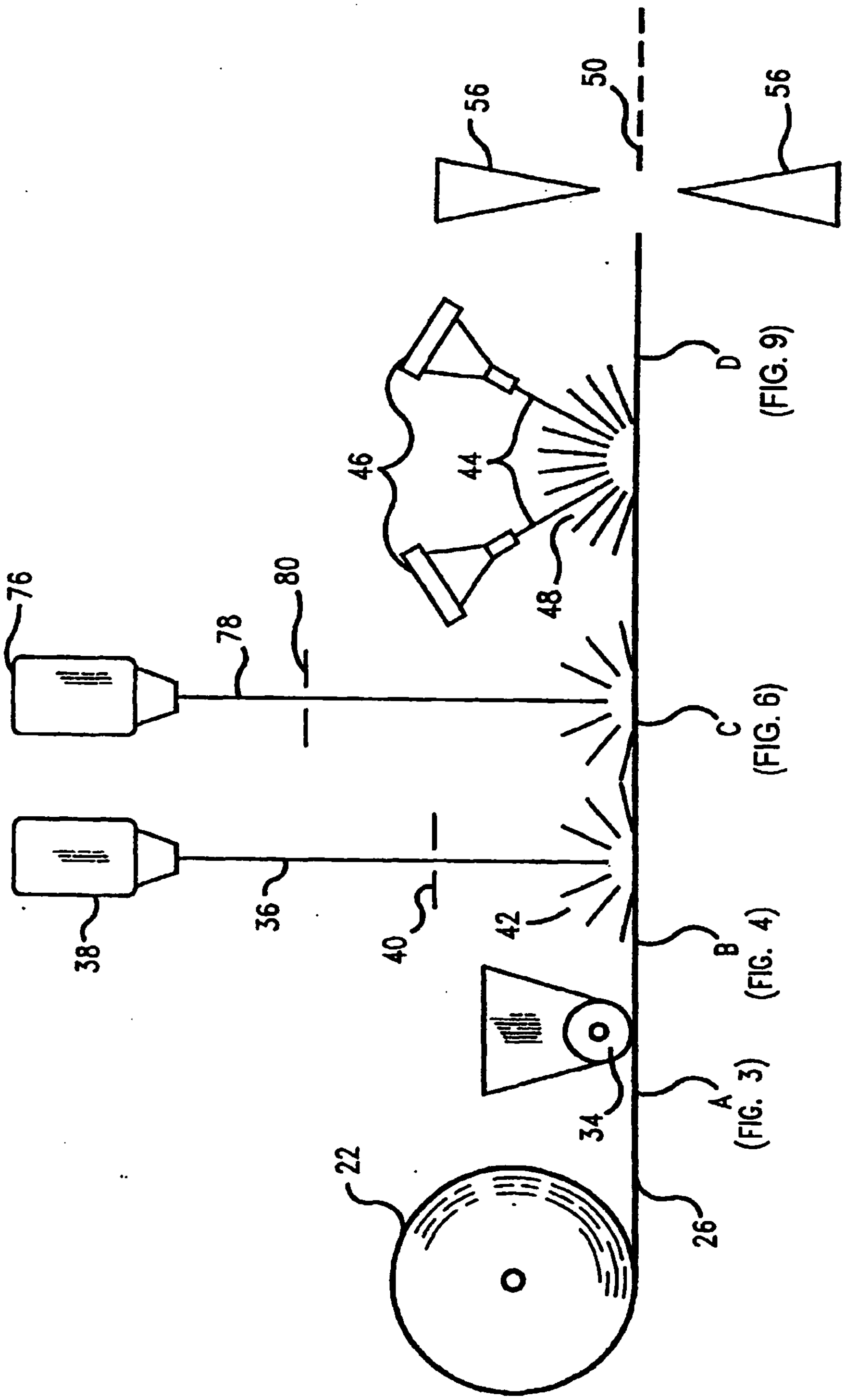
22
26
34
A
(FIG. 3)
B
(FIG. 4)
38
36
40
42
C
(FIG. 6)
76
78
80
44
46
48
D
(FIG. 9)
50
56
56

FIG. 2

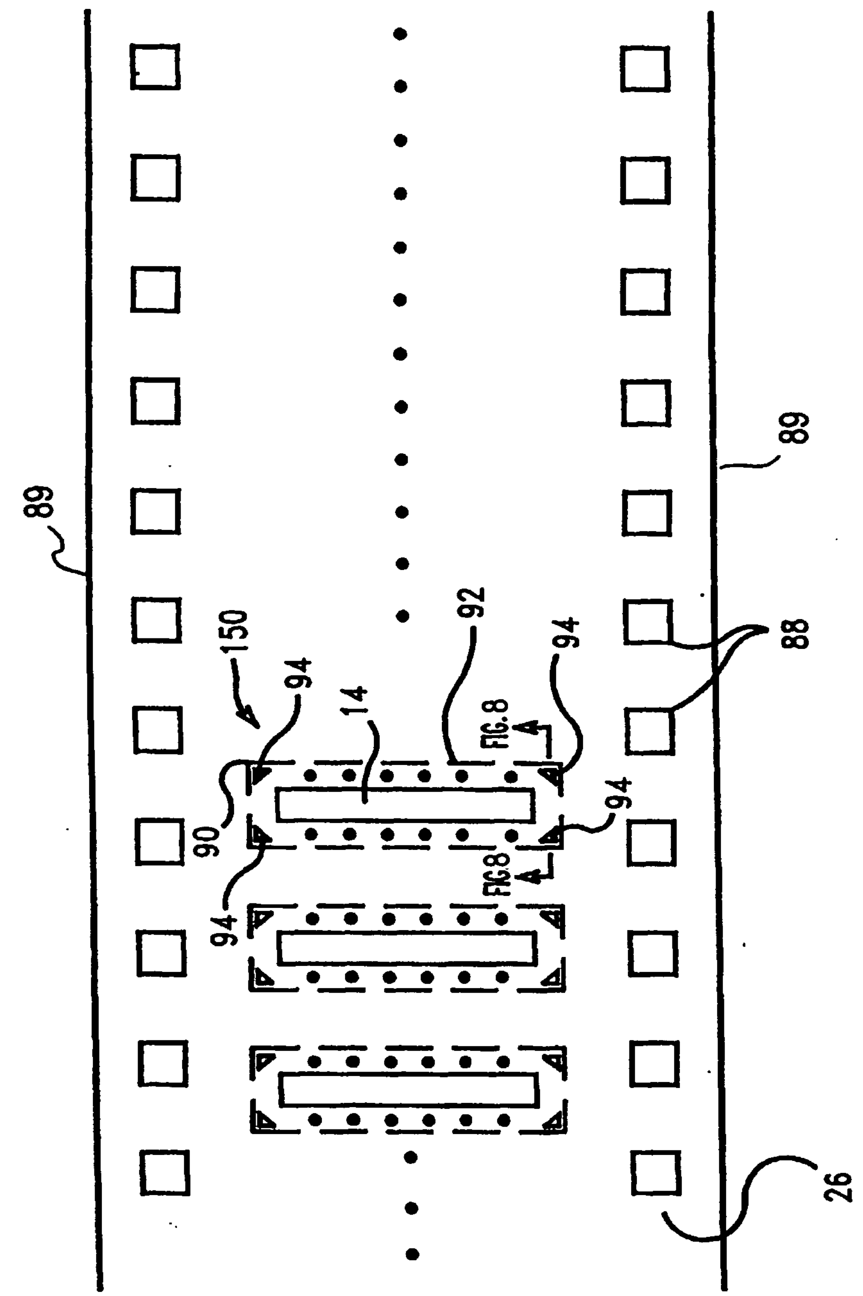

FIG. 7

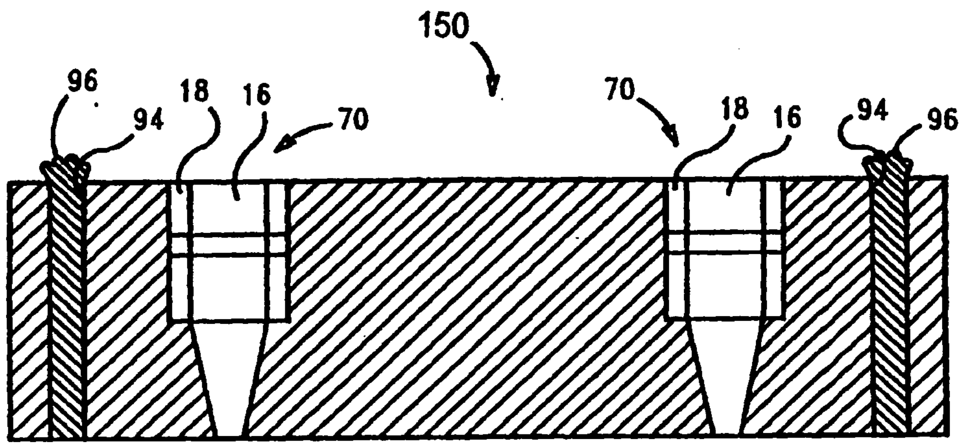

FIG. 8

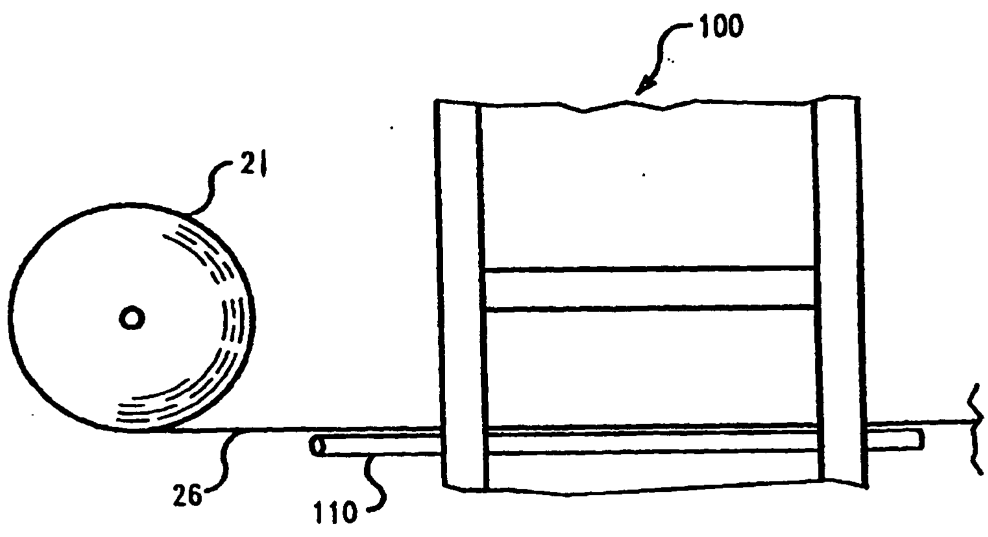

FIG. 5

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